Oilfield Service trio target Jules Verne Territory

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Expandable solid tubulars represent one of the most promising and rapidly advancing technologies in today's battle to remove the remaining barriers to deepwater and ultra-deepwater development. Several companies are hot on a trail once considered the exclusive preserve of science fiction writers. **Rick von Flatern** checks their progress.

Only rarely does a new technology promise to change dramatically the looks of an entire industry. In the upstream oil business, for instance, innovations of that scale are limited to such things as the introduction of the rotary table, the rock bit, floating drilling and production units and extended reach drilling. Today, if the engineers and scientists involved are to be believed, another such momentous shift is in the offing.

Through the relatively new technology of solid expandable tubulars (SET) it is likely a true monobore well, or what Enventure engineers call the monodiameter well to distinguish it from conventional wells of a single casing size, is just over the horizon.

'We are very close to the monodiameter well,' says Lance Cook, president and CEO of Enventure, the Halliburton-Shell joint venture widely regarded as the SET technology leader. 'It is not science fiction anymore but an engineering issue.'

The implications of the development are enormous. Cook estimates a well consisting of a single casing diameter from the surface tree to total depth could save operators about 40% in steel while producing 60% less cuttings over traditional well designs. Drilling them therefore would require similarly reduced amounts of drilling mud and cement and could be drilled and produced through smaller risers.

The knock-on effect in terms of space, weight and time would permit smaller drilling rigs to work in much greater water depths. Likewise considerably smaller production units could conceivably replace the hugely expensive, long lead time TLPs, spars and like designs necessary today to produce from waters beyond the continental shelf.

For the moment, three service companies – Weatherford, Baker and Enventure – plus Shell Technology, all with beginnings tracing back to a Shell initiative, are in pursuit of the monobore concept via SET technology. The Baker-Shell effort, known as e2Tech, has recently been purchased by Shell and Baker will pursue the technology on their own.

Shell originally chose to form three separate joint ventures to pursue the same end after an outside consultant had concluded the technology held a potential market worth several billions of dollars and that competition would drive quicker results. Shell also figured that should one effort fail, the others might prove the notion still viable whereas if all three failed it would seem a safe bet the original concept was flawed beyond redemption. Likewise, if only one group was working on the project and it failed, the whole technology may be prematurely abandoned.

Up and down through thick and thin

Leading the service industry trio, in terms of sales and product development, is Enventure. Owned 50:50 by Shell and Halliburton, Enventure installed its first

solid expandable casing across a depleted zone in order to save a casing size in November 1999. It was what the company calls a 7 5/8 in by 9 5/8 in casing, meaning it was a 7 5/8 in casing string run in the hole through a 9 5/8 in casing and then expanded to fit inside the larger string.

Distinguishable from a true monobore by the fact it reduces successive casing sizes by an amount equal to that of the pipe's wall thickness, that first installation was nonetheless significant. It offered a unique solution to one of the oil industry's greatest challenges to moving into ultradeep water – formation pore pressures and fracture gradients that in deepwater are often only fractions of a pound apart.

This proximity forces drillers to set an inordinate number of increasingly smaller casing strings to avoid either blowouts from too light a mud weight or fracturing the formation from to dense a drilling fluid. Eventually a casing size must be installed that is too small to accommodate commercial volumes of production. By using expandable tubulars as a drilling liner to cross these low-pressured or depleted zones, a casing size can be saved and the well eventually drilled to total depth with a suitably large production casing.

e2Tech has also developed a system and tools similar to Enventure's to expand a drilling liner and in some applications to create what Enrique Proano, Baker's director of global business development, describes as kind of 'metal filter cake'. In both instances cones are placed at the base of the liner to be expanded and connected to the running string. When the unexpanded liner is positioned across the offending low-pore pressure zone, a dart is landed on a collar below the cone assembly to create a hydraulic chamber and as the system is pressurized liner is forced over the cone until it contacts the bottom of the hole. The cone then moves upward expanding the casing against the bore wall. It can be used either with a sealing element behind it or simply bare against the wall. e2Tech developed this system for a high-profile project in the North Sea.

'[The operator] was casing through several depleted zones to reach production in a lower formation,' explains Proano. 'They were having difficulties while using conventional drilling techniques due to the massive loss of circulation and adding two additional telescoping casing strings would have greatly reduced the hole size across the production interval. The solution was to deploy two temporary expandable liners to cover each of the depleted zones and then to conventionally case over those to get down to the deeper target zone with the original production liner size.'

The basic philosophy of expandable tubulars is simple enough. Run a string of casing into the hole that is some size smaller than what is already there. Once in place, a tool is pushed or pulled through the new casing to force it to expand against the wellbore wall and seal against the inner wall of the previous casing. In its most basic sense it is a form of swedging that has been done for years using wireline or tubing conveyed cones to jar a cone-shaped tool through tight spots to open partially collapsed tubing.

Enventure advocates a cone pushed upwards through the expandable string via pressure. Weatherford, on the other hand, has developed its own expanding tool that is cone-shaped but fitted with rollers. The difference, according to Weatherford's Paul Metcalfe, is important.

'We use rotary expansion that uses a roller device forced through the tubing to circumferentially yield the material,' explains Metcalfe, who heads Weatherford's SET division. 'And that is an important term because it differentiates us substantially from what Enventure is doing.'

According to Metcalfe, the number and type of forces each company's process is

bringing to bear on the steel being expanded is key to differences in the final product. 'We have a number of determinants,' he point out. 'We have rpm, axial speed, we have effective connecting cone angle. We have pressure. So the more variables in the process allow us to more tailor the final end form of that pipe.'

In fact, the two methods result in profoundly differing end products (baker uses a cone and process similar to Enventure's). Enventure expands the pipe from the bottom up through pin-up connections and generates the material to allow the steel to expand outward through tubular length shrinkage. As a consequence, the final product of the Enventure process has the same wall thickness as the pre-expanded tube.

'Say we want 100ft of overlap inside the previous casing string,' explains Enventure's Cook. 'We will run 200-300ft of overlap and basically that extra is feed material we need to maintain wall thickness and when [the cone] pops through it is 100ft of overlap.'

The Weatherford method runs the tool in the opposite direction, from top to bottom which means there can be no extra steel to use for expansion without a massive rat hole from which to extract material (an impossibility by definition since the system only works if the entire length of the open hole is covered by tubing before drilling out with a higher mud weight). Weatherford's method, therefore, derives its feed material for expansion from reduced wall thickness. And though it may be counter-intuitive, Metcalfe insists the choice generates a real advantage for the final product.

'One distinct advantage of the tool is we can deform the pipe compliantly if we chose,' he says. 'We can therefore actually squeeze the material to fit exactly the form of another casing or the bore hole which means we eliminate the annulus altogether. With a fixed cone if you get it (to expand) exactly right for one section of the hole, it will be off in another where [the casing] is varied.'

Enventure's Cook is not unsympathetic to the argument but maintains it is impossible to avoid loss of (burst and collapse) capacity with wall thickness loss. 'Clearly we feel that because of the higher capacity we get ours is a better solution,' he says. 'When we test our expanded pipe for collapse, for its dimensions it very consistently falls very close to the API calculated capacities. If we can overcome the Bausinger effect we will be considerably above that.'

The Bausinger effect is significant to SET research. Essentially it says that when a material is plastically deformed in one direction it will have les resistance in the other direction than it had originally. In other words, when tubulars are expanded, the collapse resistance – the opposite direction of expansion – of the final product will be less than the original tube. As a result, the collapse rating of expanded pipe is a hot button issue on which both companies are spending considerable time and effort.

Metcalfe says, however, that his company's investigations indicate that loss of collapse resistance is less a problem with the Weatherford final product than might be expected from the loss of wall thickness because of how the roller cone works the steel.

'The interesting thing we found from our research is that the state of the metallurgy of the pipe after the process is also different than when using a fixed cone like Enventure,' he explains. 'We are getting different levels of cold work in the pipe as shown by the fact we have higher than expected collapse pressures for the final worked pipe.'

Other serious differences exist between the three company's basic approaches.

Enventure, as the leader with more continuous time devoted to SET research than its competitors, has done a great deal of work on the details of the science. It has, with the help of Lev Ring, vice president of technology, for example, proven up thread designs capable of sealing before, during and after expansion. And it has discovered that due to the manufacturing process electrical resistance weld (ERW) pipe, while suffering from the stigma of a high weld defect rate created by a 1980s study, is more uniform than standard oilfield tubulars and so better suited to expansion. Enventure has also run more SET in the hole than anyone else, experience that has allowed it to make product refinements ahead of the competition. Enventure marketing vice president Pat York says, for instance, that early operations taught the company how to speed the installation procedure significantly, no small consideration in deep water where time is lots of money.

'In the first job we went in really slowly and still we saved the operator, by its calculations, about $100,000,' he recalls. 'The experience gained, coupled with the operations learnings that have been integrated into our installation process, would realize savings closer to $400,000 were the same system to be installed today.' Says his company is also about to conquer the thread issue, a major hurdle to making any expandable systems viable over more than a few feet. 'A thread [solution] is quite well in hand because we are up to 6000psi (pressure rating) with our first prototype and now we can slice that test connection in half and analyze it and go further. It is not insurmountable by any means and we must be done by Q3 which is an internally set milestone.'

The quest

Still, it is the true monobore well that is the final goal of expandable solid tubulars and one that some industry experts insist will come to fruition in the very near future.

'We call the monobore well the Holy Grail, ' says Bakers Proano. 'We are all confident we are going to get there and the time estimates reach from two years, according to Shell, to five or six years according to more conservative estimates. But for planning we estimate we will have a full monobore offering by 2005, though it will take the industry a while to truly accept it.'

Industry expectations that a monobore solution will come later rather than sooner stem from a single complex issue. It is have solved, or at least be on the very brink of solving, just that problem and so brought considerably closer the arrival of the first true monobore installation.

'We expanded a 5 ½ in casing section normally and through that expanded string we brought another string of casing and expanded it to the same internal diameter,' says Cook, displaying a section of pipe cross-cut to reveal two lengths apparently expanded together with no discernable change of internal diameter from one section to the next. 'What we have done is reform the skirt (of the first piece) to receive the expanded second section. Now you can start with 9 5/8 in casing at the surface and drill to say 20,000ft and still have 9 5/8 in casing.'

Cook says the key was deciding on the proper material and the shape and formation process for the skirt, a flair at the bottom end of the first section of casing into which the top overlapping footage of the next section is fitted during expansion. The model on display has only one foot of overlap but nonetheless tests have proven the sections are nearly impossible to separate.

'We have only about a foot of overlap and we tried to pull it apart and couldn't,' explains Cook. 'And on one sample we welded end caps on and applied [internal] pressure to it and this one foot segment parted at about 150,000 pounds tension and never leaked. But in a real world situation we will have 40-50ft of overlap as opposed to this one foot.

'How that was accomplished is the $64,000 questions that would need Lev and several blackboards to explain,' adds Cook with a smile. 'But with this everything could be designed to run one-size casing, one-size drill pipe. You wouldn't have to lay down bottom hole assemblies, you wouldn't have to change bits, none of that. Suddenly everything is standardized.'

In essence, the breakthrough moves the pursuit of the Holy Grail from a physics problem to an engineering task. Not to say it will be on the market tomorrow. After all, there are radically different pipe manufacturing equipment and process to be developed as well as a foolproof mechanism for creating the right length and shape of the skirt and overlap. Likewise some complex metallurgical problems remain to be solved and cone designs must be worked out that will render optimal interference between the two sections.

Still, it is difficult to overstate the significance of this latest Enventure success. It will almost certainly reduce by years the arrival of the first true monobore well.

On the road to perfection

While the true single-diameter well bore still lies some distance away, the road towards it has already revealed numerous, albeit less dramatic finds, with significant value of their own. 'You learn about key components on your way to a monobore well and you spin it off as a product and you learn a lot from that and tend to accelerate the whole process,' says Weatherford's Metcalfe. 'And hopefully we will pull them altogether at the end of this year to have an expandable drilling liner which is not the monobore but is certainly one major step on the way to it.'

Indeed, Baker's Proano acknowledges that the development process leading to a monobore is as significant to his company's strategy as actually getting there. 'One of our differences [from our competitors] is that we are differentiating between the monobore well bore construction concept and all the other expandable technologies that are associated with expandable tubulars,' he adds. 'We are allowing the different product lines within Baker Oil Tools and their expertise to focus on the things we have been doing for years – on liner hangers, screens, multilaterals and packers – and we are allowing a second group to concentrate on the true monobore well bore construction concept even the two will be ultimately related.'

News of expandable sand screens installations, in particular, has been especially prominent in recent month. Weatherford, for instance, has made much of the fact it has placed several record-length in recent months and others are looking at the technology.

Baker's Proano says his company'[s long history with sand control and its systems-oriented philosophy have placed it in a position to make more of expandable screen technology than has the competition.

'Sand control is more than just the screen,' says Proano. 'We may not have been the first to market with an expandable screen but we are ready now and our product will be superior to what is on the market because we have designed it as a complete sand control system rather than a sand exclusion one.'

All three companies are also touting their work on expandable liner hangers and liner hanger packers. Baker has long had a liner based on expanded metals and Weatherford reports it is currently involved in a development project with BP driven by the implications of narrow margin between pore pressure and fracture gradient for liner hanger running operations in deep waters. 'In deepwater, you can have the problem, because of a small gap between the elastomer packoff and the casing being run, of creating a large surge pressure,' explains Metcalfe. 'With

this technology we can have pipe with big annular clearance and expand the pipe out when it is in position.'

Weatherford is also working on expandable liner hangers that need not be cemented in the ground and would be used to support long sections of expandable screens, acting essentially as a packer. 'We are going to trial runs on several of them in Oman in August and if they go well we will be off and running and marketing them worldwide for anything you might want to run on a very cost-effective 5000psi liner hanger.'

And Enventure has placed sealed, expanded packers and hangers in each of the 31 commercial SET jobs it has done and is now entering, along with partner Halliburton, into other expandable markets. 'Two weeks ago we ran the first installation of the liner as a separate product in conjunction with an expandable sand screen that Enventure is developing with Halliburton,' reports York. 'And we are developing another simply as a liner hanger.'

The company also just completed the first installation in which an expandable liner hanger replaced a conventional liner hanger and liner top packer. And last month saw the installation of the first 'nested' system – a 5 ½ in x 7 in system expanded inside an expanded 6 in by 7 5/8 in system. 'This [nested] type of installation is a precursor to the monodiameter well,' explains Cook.

To the center of the earth?

While it seems fantastic, given enough pump horsepower, it is theoretically possible to drill to the earth's mantle using a true monobore design. The implications of removing casing size as a limiting factor also means the distance a well could be drilled horizontally is also limited only by the ability to transport fluids and cuttings between bit and surface. Likewise, by extension and applying the same methods to multilateral wells, would render the number of branches possible off any main well also limitless.

Ironically, the very fact it is such a magnificent technological leap forward may hinder its entry into the main stream of well design. The tradition-bound oil industry has long been known for its resistance to the untried. And as Enventure's Pat York puts it, 'The stranger the design the longer the acceptance curve and it is just mind-blowing the kind of changes monodiameter wells will make.'

Still, before the decade is out, wells of a single diameter from tree to TD are a certainty. The technology is too far advanced and the cost implications too great for them to be ignored for very long even in the hide-bound drilling and completion industry. **OE**